As early as the 10th of March surface winds over Alabama were uniformly from the northeast and of continental origin. On the 11th they had become easterly, and on the 12th, when general rains began, they had shifted to southeast and were of oceanic origin. On this date the barometric gradient due to the oceanic anticyclone acting jointly with the gradient due to a cyclone centered over eastern Colorado doubtless caused an acceleration of the southeast winds and they continued throughout that and the following day.

The upper winds on the 13th, 14th, and possibly for a part of the 15th must have been from a westerly quarter, basing this statement on the well-known turning of the surface winds with altitude.

As previously stated, the development and movement of the middle Mississippi Valley cyclone of the 15th must have resulted in a more northerly component being injected into the upper winds over east Gulf States on that date.

The longer axis of the area of heavy rains on the 14th was in a n./s. direction, and on the 15th it was ne./sw. when the areas contiguous to Alabama are considered. The isohyetal chart (fig. 1), however, gives the impression that the heavy rains were local to the watersheds under discussion.

It may be asked, how was the excessive rain distributed throughout the 24 hours? The answer for a single station having an automatic register is found for Mobile, Ala. Excessive rains occurred at that station on March 12, 13, and 14. The maximum amount for any 24 hours was 11.59 inches on the 14th and 15th. The excessive rate began at 3:46 a. m. and ended temporarily at 4:13 a. m. The rate continued as shown in the exhibit below:

Mobile, Ala.

Date	Excessive rate— Began	Ended	Amount	Rate per minute
Mar. 14	3:46 a.	4:13 a.	0.76	0.028
Do	5:08 a.	5:58 a.	.95	.019
Do	5:58 a.	6:48 a.	.66	.013
Do	6:48 a.	7:38 a.	.82	.016
Do	7:38 a.	8:28 a.	.85	.016
Do	8:28 a.	9:18 a.	1.03	.021
Do	9:18 a.	10:08 a.	.68	.014
Do	9:54 p.	10:56 p.	1.48	.024

The bulk of the excessive rain at Mobile fell therefore during the 7 hours and 11 minutes that elapsed between 3:46 a. m. and 10:56 a. m. of the same day. During that time 6.71 inches fell or at the rate of 0.016 inch per minute. Naturally there were occasions during that time when the average rate was greater, as shown by the following tabulation:

Time	Maximum amount	Rate
	Inch	*Inch per minute*
5 minutes	0.40	0.08
10 minutes	.71	.07
15 minutes	.97	.06
30 minutes	1.67	.06
60 minutes	2.32	.04
120 minutes	2.66	.02

For comparative purposes the record of the greatest 24-hour rainfall in the United States which occurred at Taylor, Tex., September 9 and 10, 1921, is given below: [1]

Time	Maximum amount	Rate
	Inch	*Inch per minute*
5 minutes	0.72	0.144
10 minutes	1.12	.112
15 minutes	1.47	.098
30 minutes	2.56	.085
60 minutes	4.25	.071
120 minutes	7.51	.063

The 24-hour rainfall at Taylor was 23.11 inches; of this amount there is a continuous automatic record for the 3 hours 6:42 p. m. to 9:42 p. m. of the 9th and the catch during that time was 10.44 inches, or an average rate of 0.058 inch per minute. As in the previous case I give the maximum rates for the storm during 5, 10, 15 minute periods, etc.

The rains at Taylor were associated with a thunderstorm and this was also the case at Mobile; we are therefore able to conclude that the exceptionally heavy rains in both cases were the result of violent convective action.

RECAPITULATION

The immediate and direct cause of the overflow was the heavy downpours of rain on March 14 and 15 in the basins of the Choctawhatchie and Conecuh Rivers at a time when due to previous rains the soil was saturated with water and the streams were at bankful stages. Other contributing causes were the slight slope of the rivers in that part of Alabama and consequently the very slow disposal of the water by the trunk streams. The fact that the local drainage at Elba and Brewton permitted a large volume of water to be passed into the trunk stream at those points undoubtedly was a very considerable factor in the flooding that took place.

[1] cf. McAuliffe J. P., Excessive rainfall and floods at Taylor, Tex., Mo. Wea. Rev. 49: 496–97.

551.578.1 (759)

SOME CHARACTERISTICS OF THE RAINY SEASON AT TAMPA, FLA.

By WALTER J. BENNETT, Meteorologist

The conventional and convenient division of the year into four seasons of three months each is not entirely satisfactory for central Florida. Considering temperature, we have winter, including December, January, and February; spring, March, April, and May; but when we come to summer we must take in four months, June, July, August, and September, for September averages only 1.4° cooler than August. This leaves us only two months, October and November, for the autumn.

Considering precipitation, the four summer months stand together because of abundant rainfall. Almost two-thirds (61 per cent) of the average annual rainfall occurs in these four months—that is, in one-third of the year. September, the driest of the four, has more than twice as much rain as May or October. During this season the probability of a measurable amount of rain on any day is 52 per cent, or a little better than one day out of every two; and the probability of a trace or more of rain is 64 per cent, or not quite two days out of every three. During the other eight months the probability of 0.01 inch of rain any day is 21 per cent, or only one day out of five; and of trace or more of rain 29 per cent, or less than one day out of three. The average daily rainfall for the rainy season is 0.23, for the other eight months only 0.08.

The actual rainy season for any particular year, of course, does not coincide exactly with the calendar months. It is sometimes difficult to say just when it does begin or end, but we consider it as beginning when rains occur with fair regularity one day out of two and as ending when rains become less frequent.

Table 1 gives the dates of beginnings and endings for each year since 1890, the total duration of the rainy season in days, the total precipitation for those days, and the percentage of the total annual rainfall.

TABLE I.—*Dates of beginnings and endings of rainy season; total duration in days; total rainfall and percentage of total annual rainfall*

Year	Beginning—	Ending—	Duration	Total rainfall	Per cent of annual
1890	May 24	Oct. 2	132	46.20	------
1891	June 8	Oct. 15	130	31.57	71
1892	June 2	Oct. 1	122	31.99	69
1893	May 30	Oct. 3	127	28.69	59
1894	May 26	Oct. 9	136	52.55	79
1895	May 30	Sept. 15	109	28.77	57
1896	May 20	Sept. 21	125	41.10	69
1897	June 3	Sept. 30	120	33.26	61
1898	June 1	Sept. 27	119	38.65	76
1899	do	Sept. 21	113	40.99	64
1900	June 6	Sept. 16	103	23.26	42
1901	June 2	Oct. 3	124	27.76	66
1902	May 29	Sept. 23	118	35.18	70
1903	June 6	Sept. 18	105	31.24	55
1904	do	Sept. 20	107	22.54	50
1905	June 9	Sept. 30	114	37.20	73
1906	May 14	Oct. 2	142	40.96	79
1907	June 20	Sept. 29	102	27.11	60
1908	June 11	Sept. 30	112	21.40	66
1909	May 29	Sept. 21	116	37.19	79
1910	June 8	Oct. 18	133	30.77	74
1911	June 3	Sept. 27	117	24.77	56
1912	May 29	Oct. 4	129	44.70	67
1913	June 21	Sept. 21	93	26.35	59
1914	May 31	Oct. 5	128	23.94	51
1915	May 29	Oct. 8	133	23.81	52
1916	June 8	Sept. 18	103	26.52	66
1917	June 10	Sept. 30	113	27.33	73
1918	June 9	Oct. 5	119	21.38	59
1919	May 20	Sept. 20	124	32.35	60
1920	June 2	Sept. 30	121	28.84	58
1921	June 21	Sept. 10	82	17.19	35
1922	do	Oct. 3	105	27.85	58
1923	May 14	Sept. 27	137	25.31	68
1924	June 2	Oct. 11	132	33.67	61
1925	May 16	Sept. 19	127	41.52	68
1926	May 25	Oct. 5	134	26.55	59
1927	June 7	Sept. 21	107	21.65	62
1928	June 10	Sept. 30	113	33.30	69

The rainy season may begin as early as the middle of May (May 14, 1906 and 1923), or may be delayed as late as the middle of June (June 21, 1913, 1921, and 1922). The ending may be before the middle of September (September 10, 1921), or run past the middle of October (October 18, 1910). The average beginning is about June 2, and the average ending about September 28, making an average duration of 119 days. The shortest on record was only 82 days (1921), and the longest 142 days (1906). The wettest rainy season was from May 26 to October 9, 1894, during which time 52.55 inches of rain fell; and the driest rainy season was in 1921, when only 18.67 inches fell from June 21 to September 10.

Sometimes there will be a shower every day for a week or longer. The longest period with rain every day (trace or more) was 26 days, July 28 to August 22, 1905. During this period 14.65 inches of rain fell. The greatest rainfall on record in 24 consecutive hours was 6.56, September 20–21, 1897. The greatest 2-day rainfall was 8.65, and the greatest 3-day rainfall 13.19, both in September, 1912. Very heavy rain may fall in a very short time. The records for 5, 10, and 15 minutes are held by September 26, 1924, when 1.05 fell in 5 minutes, 1.66 in 10 minutes, and 2.03 in 15 minutes. The records for half-hour, hour, and 2-hour periods are held by August 28, 1925, when 2.72 fell in half an hour, 4.01 in one hour, and 4.59 in two hours. Excessive precipitation as heavy as an inch or more an hour occurs between three and four times per season, and a rainfall of an inch in 24 hours, about nine times per season.

Often there is a break during the rainy season of a week or more. The longest period without rain during this season was 11 days in June, but periods of 9 days without rain have occurred in July, August, and September. Showers are most common in the afternoon, and an all-day rain is practically unknown.

The average daily duration of rainfall, *including* traces has been calculated for a period of 24 years, 1905 to 1928, and it has been found that June has an average of 1 hour 23 minutes per day; July, 1 hour 32 minutes; August, 1 hour 36 minutes; and September, 1 hour 23 minutes. For the whole season the average is 1 hour 29 minutes, practically 1½ hours per day, or about 6 per cent of the time. Thus it happens that the average daily duration of rainfall for the rainy season at Tampa, is exactly the same as the average daily duration for the whole year at Baltimore, the Baltimore record *excluding* traces. (Mo. Wea. Rev., Feb., 1929, pp. 50–52.) The month with the least duration was September, 1910, with an average of 15 minutes per day, and the month with the greatest duration was June, 1912, with an average of 4 hours 48 minutes per day.

Table 2 gives the average duration per day of rainfall, including traces, for the months of June, July, August, and September and for the season, each year from 1905 to 1928, in hours and minutes.

TABLE 2.—*Average daily duration of rain (including traces) in hours and minutes*

Year	June	July	August	September	Season
1905	1:05	1:37	3:17	2:16	2:04
1906	1:29	2:07	2:04	1:03	1:41
1907	1:23	1:12	1:21	1:23	1:19
1908	1:52	1:04	2:06	2:16	1:49
1909	2:07	2:28	2:37	0:40	1:58
1910	1:42	2:02	1:34	0:15	1:24
1911	1:07	1:44	2:06	1:10	1:32
1912	4:48	1:15	1:04	3:03	2:31
1913	0:47	1:16	2:02	0:59	1:16
1914	1:09	1:01	0:49	1:31	1:00
1915	0:42	1:06	1:13	0:45	0:57
1916	1:06	1:07	1:33	1:40	1:22
1917	0:56	1:16	2:20	1:26	1:30
1918	0:35	0:48	1:29	0:57	0:57
1919	1:02	2:31	0:46	0:50	1:18
1920	1:07	1:36	1:19	1:48	1:27
1921	0:40	2:20	0:38	0:30	1:02
1922	1:14	1:36	1:58	2:22	1:48
1923	1:28	1:14	1:16	1:06	1:15
1924	1:03	1:50	0:53	1:19	1:16
1925	1:09	1:47	1:12	0:30	1:10
1926	2:03	1:17	1:24	1:37	1:35
1927	1:03	1:31	0:51	0:44	1:02
1928	1:34	1:16	2:25	3:48	2:15
Means 1905 to 1928	1:23	1:32	1:36	1:23	1:29

In spite of the heavy rains, there is usually an abundance of sunshine. Up to noon the sunshine runs 74 per cent of the total possible. The records for the past 32 years show that there are only two or three days per summer with no sunshine at all. The average per cent of possible sunshine is 67 for June, 62 for July, 65 for August, and 66 for September. The average daily duration of sunshine is June, 9 hours 16 minutes, or

9.3 hours; July, 8 hours 35 minutes, or 8.6 hours; August, 8 hours 29 minutes, or 8.5 hours; and September, 8 hours 12 minutes, or 8.2 hours.

During the eight months, October to May, the rainfall is to a large extent due to areas of low pressure crossing the country, and is therefore usually associated with barometer readings below normal. Occurrence is almost as frequent at night as during the day. The rainfall of the rainy season, however, is mostly due to local thundershowers, which are more probable in the afternoon than in any other portion of the day. They occur nearly as often with high barometer as with low. From a 5-year computation, 1924 to 1928, the probability of rain for June, July, August, and September during a day following an 8 a. m. barometer reading of 30.00 or above is 60 per cent; while the probability of rain with the barometer below 30.00 is 69 per cent.

Thunderstorms.—The thunderstorm is an important element in the climatology of Tampa, and of particular importance during the rainy season. A thunderstorm is recorded whenever thunder is distinctly heard at the station, even though neither lightning nor rain is observed. This is in accordance with instructions, practically unchanged since 1890. (Mo. Wea. Rev., July, 1915, p. 323.) During the early years, up to and including 1903, thunderstorms apparently were not so carefully recorded. The average number of thunderstorms, 1890 to 1928, is 81 per year, of which 61, or 75 per cent, were during the rainy season. The average number, 1904 to 1928, is 94 per year, of which 73, or 78 per cent, were during the rainy season. There is a wide variation in the number of thunderstorms from year to year. Nineteen hundred and four had 123, and August of that year had a thunderstorm every day. The year 1908 had only 73 thunderstorm days. Comparison with the records of other cities show that Tampa has more days with thunderstorms than any other regular Weather Bureau station in the United States.

The causes of this frequency are not hard to find. Insolation is intense from a sun that nearly reaches the zenith at meridian height, while the warm waters of the adjacent Gulf of Mexico furnish an ample supply of moisture. Conditions thus favor the formation of local or heat thunderstorms. Also, wind directions are favorable. The prevailing wind direction at Tampa is northeast, for the city is within the trade-wind belt for a large part of the year. But because of the unequal heating of the land surface of the peninsula and the water surface of the Gulf, we have a sea breeze, or prevailing winds from the southwest and west in the afternoons during summer. Often, however, while the winds are from the southwest, clouds can be observed moving from the northeast, showing that the sea breeze does not extend very high. I shall not attempt to explain the exact mechanism of the thunderstorm, but while they are of local or heat origin primarily, their formation is apparently helped by a rolling up of the vapor-laden air from the Gulf, as it meets the prevailing northeast winds.

The average amount of cloudiness for the rainy season at 8 a. m. (39 years) is 4.0 tenths; the average for 12:30 p. m. for the past 11 years is 6.5 tenths, showing how cloudiness increases up to noon. In the afternoon the increase is more marked up to 5 p. m., although no observations are available for averaging at that hour. There is probability of thundershowers somewhere in central Florida any day during the months of June, July, August, and September, although often they are widely scattered and cover only a small total area. A marked low-pressure area replacing the normal high over Bermuda and the South Atlantic coast usually causes a cessation of thundershowers in the Florida Peninsula, but the occurrence during the rainy season is quite rare.

Thunderstorms occur mostly in the late afternoon, but they may occur at any hour, and one day may have several distinct storms, as many as four in one day having been recorded. Showers that resemble thundershowers, even to making a record of a pronounced thunderstorm "nose" on the barograph trace, are sometimes noted when no thunder is heard. According to existing instructions these are not classified as thunderstorms.

As to damage by lightning, there seems to be no more in Florida than in some of the northern States where thunderstorms are less frequent. In tropical and subtropical countries lightning seems to pass more frequently from cloud to cloud and less frequently from cloud to earth. (Ward's Climate, p. 87; Humphrey's Physics of the Air, W. B. Edition, 1920, pp. 320, 354, 355.)

Hail has been recorded in the vicinity of Tampa only thirteen times in the past 39 years, and only four times during the rainy season. Apparently temperatures in the thunderheads rarely reach as low as the freezing point.

During the summer season we have a thunderstorm about one day out of every two, and one is particularly likely to form whenever the temperature threatens to go too high for comfort, and when the humidity seems oppressive. Coming in the afternoon, just before the time we might expect the maximum temperature, such a storm cuts off the peak of the temperature curve and causes a sharp drop, a fall of 15° in half an hour being quite frequent. Although the temperature may rise again after the storm is over, it never goes as high as it was before. This is one of the reasons why Tampa can say that the official thermometer has never gone above 97½°, and that a temperature of 95° or above occurs only once in a summer on the average.

Hourly distribution of rain and thunderstorm.—During the eight months, October to May, rain is almost as likely one hour as another. But during the summer season the probability of rain is very much greater during the afternoon hours, amounting to 21 per cent for the hour ending 5 p. m., while for the hour ending 4 a. m. the probability is only 3 per cent. The thunderstorm curve shows a still greater range, the probability for the hour ending 5 p. m. being nearly 22 per cent, and for the hour ending 5 a. m. only 1 per cent. The percentages of probability for the different hours are shown by Table 3 and also on the accompanying figure. We can not add these percentages together, however, to get the probability of rain in two or more hours, for the same shower or thunderstorm may extend through two or more hours and so be counted more than once. These percentages of probability of rain were obtained by counting the total number of individual hours in the past 24 years in which rain (trace or more) was recorded, and then dividing the sum by the total number of days, 24 × 122 or 2,928. The thunderstorm figures were obtained in a similar manner.

The average amount of rainfall for each hour during the rainy season has also been calculated by adding together the rainfall for each hour, and then dividing by 2,928. The hour of greatest rainfall is from 4 to 5 p. m. with an average of 0.028 inches. From 3 p. m. to 7 p. m. the average hourly rainfall is above 0.02. The hours of least rainfall are from midnight to 8 a. m. running from 0.002 to 0.004. These hourly figures can be added together to get the average rainfall for any group of hours. For example, the seven hours 10 p. m. to 5 a. m. have only 0.020 inch; while the four hours from 3 p. m. to 7 p. m. have 0.103-inch rainfall.

TABLE 3.—*Average hourly rainfall, probability of rain, probability of thunderstorm, June, July, August, and September, 1905–1928*

Hour ending	Average rainfall	Probability rain, per cent	Probability thunderstorm, per cent	Hour ending	Average rainfall	Probability rain, per cent	Probability thunderstorm, per cent
1 a. m.	0.003	3.3	1.0	1 p. m.	.001	13.3	8.4
2 a. m.	.002	2.8	1.0	2 p. m.	.012	14.8	11.3
3 a. m.	.003	3.3	1.1	3 p. m.	.017	16.3	16.4
4 a. m.	.002	3.1	1.2	4 p. m.	.024	19.2	21.6
5 a. m.	.003	3.5	1.0	5 p. m.	.028	20.9	21.8
6 a. m.	.004	3.7	1.1	6 p. m.	.027	20.3	19.7
7 a. m.	.004	4.0	1.7	7 p. m.	.024	20.4	16.1
8 a. m.	.004	5.5	1.6	8 p. m.	.014	18.8	10.9
9 a. m.	.005	6.0	1.8	9 p. m.	.008	15.4	6.7
10 a. m.	.006	8.0	2.6	10 p. m.	.005	9.3	4.2
11 a. m.	.007	9.2	3.5	11 p. m.	.004	6.7	2.3
Noon	.009	10.9	5.2	Midnight	.003	4.3	1.6

The relative humidity runs usually above 80 per cent during the night, while during the day there is a marked drop. The curve is almost the inverse of the temperature curve, and from noon to 4 p. m. the average relative humidity is between 50 and 60 per cent. (M. W. R., July, 1919, pp. 466–468 and Oct., 1919, p. 710.) This compares very well with afternoon readings in many of the interior cities, and shows that the humidity is rarely oppressive during the rainy season. Although the rainfall is heavy, the sandy character of the soil allows a rapid run-off. There is little standing water and no mud. The moisture taken up into the air is rapidly distributed by

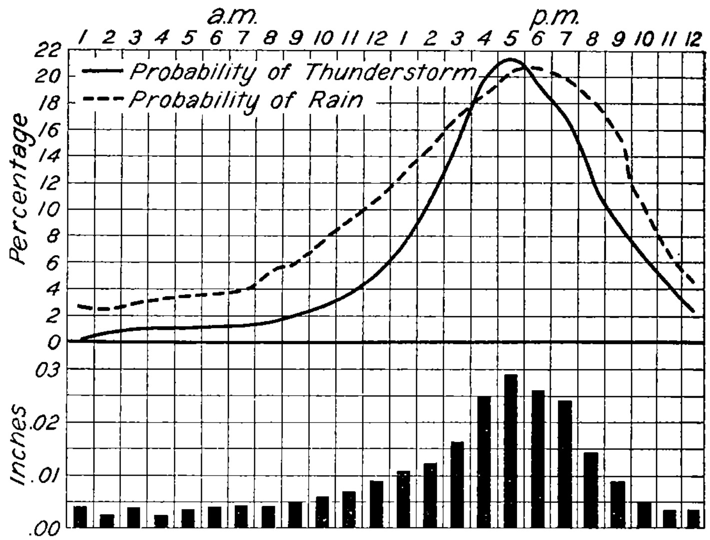

FIGURE 1.—Hourly probability of rain, a thunderstorm and the average precipitation for each hour of the day at Tampa, Fla.

the horizontal air movement and active convection currents, and the humidity is very rarely felt as oppressive

CHANGE IN DENSITY OF SNOW COVER WITH MELTING[1]

551.578.46 (794)

By GEORGE D. CLYDE

[Utah Agricultural Experiment Station, Logan, Utah, July 11, 1929]

Measurements of the density of snow have been made in the Sierra Nevada Mountains for many years. At Summit, Calif., measurements of density at foot intervals in depth have been made over a period of five years. These records indicate no uniformity in density in different layers of deep snow. This variability is due to changing weather conditions during the accumulation of snow cover. Ice layers and crusts form at different intervals during the accumulation period. Measurements in California indicate no relationship between density of top layer of snow cover and the lower depths.

During the spring of 1928 a study was made of snow-melting characteristics on the Wasatch Plateau in central Utah. This plateau rises to an elevation of 10,500 feet. The studies were made on the snow cover at elevations of 8,000 to 10,000 feet. Measurements were made to determine the change in density with depth, and it was found that before melting began and while the average density was still increasing with the advance of spring that there was a marked difference in density at different depths due to ice layers and hard crusts. As the spring advanced and daily temperatures rose it was noticed that these hard layers disappeared and the snow cover took on almost a uniform density from top to bottom. On April 26 a snow profile was obtained which clearly indicated these hard layers. The mean temperature on that day was 45.5° F. At the time of observation at 3 p. m., temperature 80° F., water was running along the top of each layer and dripping off at the outcrop. The surface of the snow was melting and the water was seeping down through the snow layer. When this water struck the impervious ice layer it started moving laterally. The temperature of the water being slightly higher than the ice crust it was gradually softened, the snow layer finally taking on a nearly uniform density. Measurements on April 23 showed the presence of ice layers and crusts throughout the snow depth. By April 30 these layers had entirely disappeared. The following table shows the uniformity of density with depth during the melting period.

TABLE 1.—*Snow west of Mammoth Ranger Station (Wasatch Plateau-Manti National Forest, San Pete County, Utah)*

No.	Depth (inches)	Core (inches)	Water content	Density (%)
A. May 10, 1928. After raining all night 8 a. m.:				
1	4	30	12.0	40.0
2	12	30	12.2	40.7
3	18	30	12.0	40.0
4	24	30	12.0	40.0
B. May 11, 1928. 7 a. m.*:				
1	3	30	10.0	33.0
2	12	30	12.5	41.6
3	18	30	12.5	41.6
4	24	30	11.5	38.3
C. May 12, 1928. After 63 inches of rain had fallen during the day. 6 p. m.**:				
1	4	30	11.8	39.3
2	12	30	12.0	40.0
3	18	30	12.0	40.0
4	24	30	11.5	38.3

* Froze previous night, causing granulation on top and bottom. Drainage from bottom during freezing reduces density on bottom.

** Snow seems to be same density after rain as before, indicating that rain goes right through.

With the snow melting well under way the density during the day is quite uniform throughout the depth. However, if the measurements are made after the snow solidifies at night, the density will be a little lower at the surface and near the bottom. This is probably due to the draining of the free water from these areas after the snow starts solidifying under the decreased temperatures. This difference in density of the upper and lower layers after freezing becomes more marked as the snow cover gets thinner.

[1] Contribution from Department of Irrigation and Drainage, Utah Agricultural Experiment Station. Publication authorized by Director, July 11, 1929.